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The body can be viewed from the next page.

A New Finishing Plant for Cold Rolled Stainless Steel Sheets*

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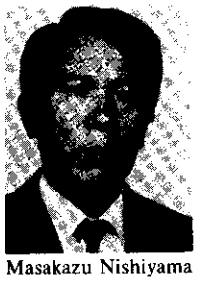

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Synopsis:

A new finishing plant for stainless steel sheets was built in Hanshin Works and went into operation on May 1983. In order to improve material flow, various facilities which had been distributed over the entire cold strip shop were integrated in the new plant, which has many features in mechanisms and systems.

The new plant consists of the following facilities: a slitting line (3 600 t/month), recoiling line (5 000 t/month), coil shearing line (3 000 t/month), and stretching-shearing line (2 300 sheet/month).

Auxilialy facilities such as the reinspection table, packing line and automated warehouse for semifinished sheet products are connected to the coil shearing line with carriage conveyer systems.

1 Introduction

Hanshin Works constructed a new stainless steel finishing plant in May 1983. In the conventional stainless steel finishing plant, multi-type, small-quantity products are often handled in more or less a batch-type operation: thus its labor productivity is liable to become lower than in ordinary steelworks facilities such as the cold rolling plant and annealing plant.

The key point to the construction of the new stainless steel finishing plant is a higher labor productivity by increasing efficiency of individual facility and integrating all those facilities, by improving the layout to rationalize the material flow, by making facility functions continuous and synchronized, and by achieving mechanization and automation of various facilities.

The main features of the construction of the new stainless steel finishing plant are as follows:

(1) A material flow ranging from the receiving of stock material coils to the shipment of finished products has been so laid out as to achieve higher efficiency.
(2) Three slitting lines have been integrated into a single recoiling line and a single slitting line.
(3) Three coil shearing lines have been integrated into a single line, with the slitting function and vinyl film laminating function synchronized.
(4) At the coil shearing line, an on-line surface defect inspection system and on-line packing system have been developed.
(5) The sheet stretching function and the sheet shearing function have been incorporated into a single continuous line.
(6) The new layout has been designed to minimize handling between facilities, with unattended handling aimed at.

Details of the above measures will be introduced below.

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2 General Layout

The layout of the new stainless steel finishing plant is shown in **Fig. 1.** The material flow of the new finishing plant is described below.

(1) The raw material coil is transported from the rolling yard to the material yard by a self-running buggy, and temporarily stored at the material yard.
(2) Stock material coils for finishing are supplied to the slitting line or recoiling line by a crane of one-man operation. The finished coil products are packed at the packing yard and sent to the shipping yard by a rail car.
(3) Stock material coils for making sheet products are supplied to the coil shearing line in the same way as above, and cut and piled sheets are sent to facilities such as the stretching-shearing line, reinspecting table, and sheet packing zone by respective conveyors.

3 Specifications and Outlines of Facilities

3.1 Coil Product Processing Facilities[1)]

3.1.1 Recoiling line

Line constitution is shown in **Fig. 2**; facility specifications are shown in **Table 1.** This line performs rewinding, trimming, inspection, and shearing of the cold rolled coil.

This line has the following features:

(1) In starting winding of the coil around the tension reel, a belt wrapper is used. Threading of the coil and that of insert paper are interlocked, and after they are wound around the tension reel, the recoiling line is changed over to the operation mode.
(2) At the time of coil shearing, the line is automatically decelerated into moderate speed before the coil shearing point. After shearing by the shears, the left-over coil is wound into the entry side, and changed-over to the next coil in a short time.

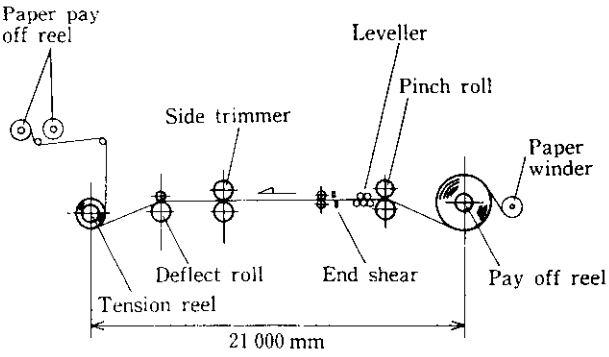

Fig. 2 Recoiling line

Table 1 Main specifications of recoiling line

Item	Specification
Coil weight	17 000 kg max
Strip thickness	0.3-3.0 mm
Strip width	600-1 300 mm
Line speed	150 m/min max

3.1.2 Slitting line

Line constitution is shown in **Fig. 3**; facility specifications are shown in **Table 2.** This line performs slitting,

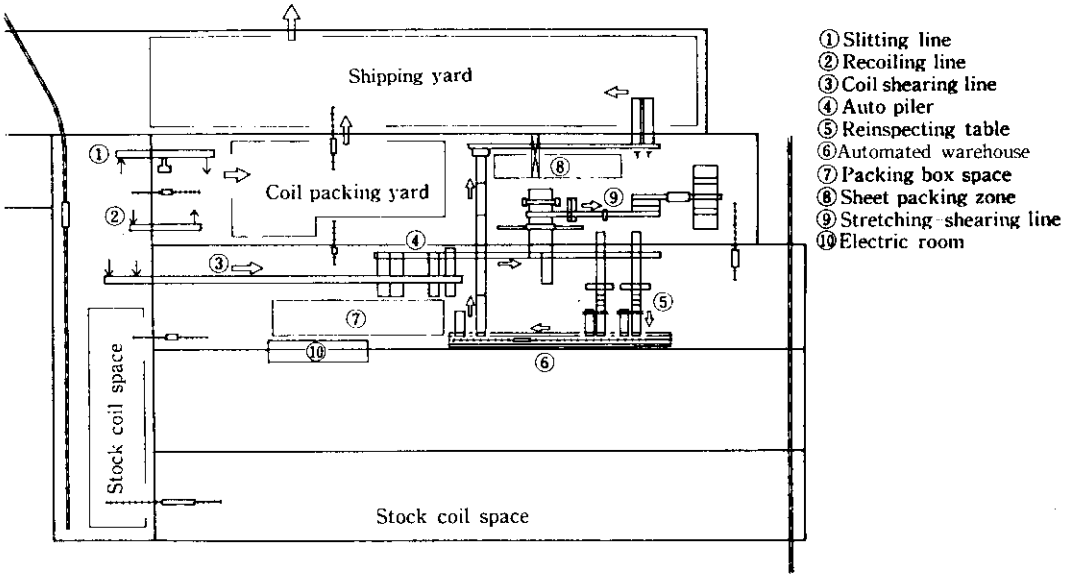

Fig. 1 Layout of stainless finishing line

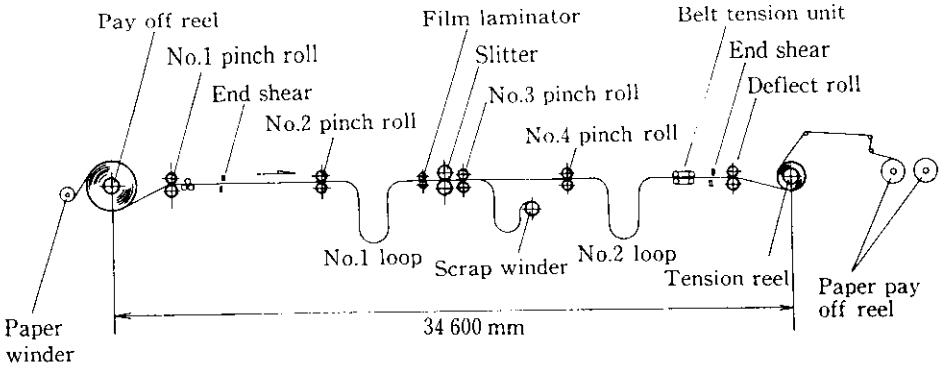

Fig. 3 Slitting line

Table 2 Main specifications of slitting line

Item	Specification
Coil weight	17 000 kg max
Strip thickness	0.3-3.0 mm
Strip width	600-1 300 mm
Line speed	110 m/min max

vinyl film lamination, inspection and shearing of the coil.

(1) The slitting system basically uses the pull-cut type by the tension reel, but a drive-cut type is also available for slitting thin gage strip.
(2) To improve the operation factor of the line, a method of performing cutter setting at the off-line, namely, the stand-changing system is adopted, and the line incorporates a unit of one-strand exclusive-use trimmer, thereby having three stands in total.
(3) As the tensioning unit, a belt[2] is used to prevent the generation of scratch.
(4) The entry side is provided with a leftover-coil-removing device.
(5) An automatic operation system is adopted which performs threading and line-speed acceleration and deceleration according to a given program.
(6) The scrap winder has a tension control system and a speed control system for thin gage strip.

3.2 Sheet Product Processing Unit

3.2.1 On-line inspecting and packing system

The conventional processing method of sheet products is basically described below. Sheets cut from a stock coil were temporarily piled up on a pallet, which was transported into the inspection yard by a crane. Then the sheets on the pallet were inspected visually one by one, and accepted sheets were placed into a prescribed box, while rejects were also placed into boxes after being sorted out by type of steel.

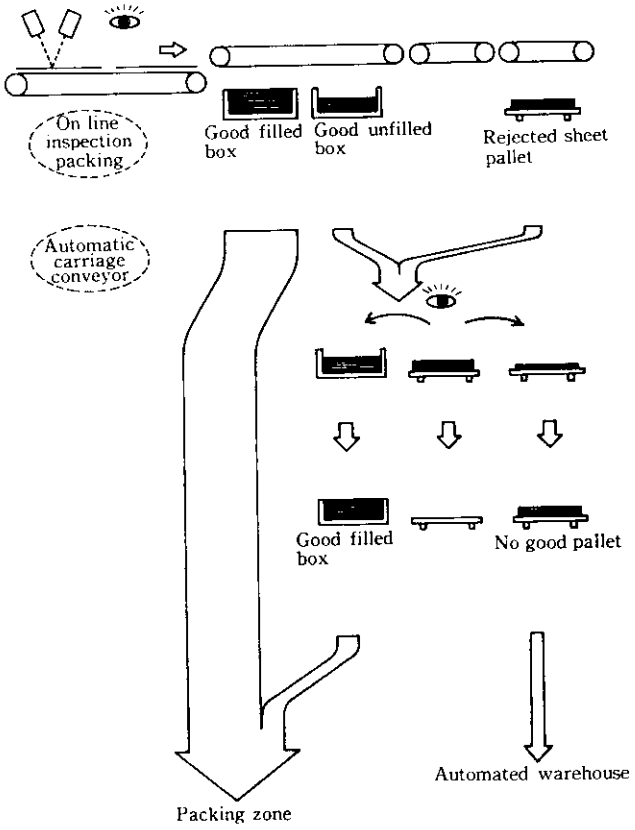

Fig. 4 On-line inspection & packing system

In the newly-developed system, however, the shear line is first provided, as shown in **Fig. 4**, with an automatic surface defect inspection system[3], and additionally, a visual inspection is conducted, thereby ensuring highly-accurate inspection. Sheets which have successfully passed this inspection are packed by the prescribed method, that is, by stacking them directly into a box or on a pallet. The number of sheets cut at the shear line is controlled by a sum of the number of accepted sheets and of previously rejected sheet expected to be accepted following subsequent reinspection.

Therefore, some of the prescribed boxes may either be fully packed with accepted sheets, or otherwise not packed fully. The fully-packed boxes are sent directly to the packing line by the conveyor line. At the packing line, the boxes are covered with lids and transported to the shipping yard.

The good unfilled box which is filled with accepted sheets but not filled to the full, and the pallet loaded with rejected sheets are both sent in a pair to the reinspection table, where the rejects are, for the first time, inspected visually and sorted out into the boxes for reject sheets which have beforehand been taken out automatically from the automated warehouse. The boxes which have been filled to the full with accepted sheets are transported to the packing line, while the boxes filled with rejected sheets are again stored in the automated warehouse.

In this way, inspection and handling operations have been greatly improved through the newly-developed on-line inspection and packing system, thereby reducing the load of visual inspection to less than 20% of the conventional level.

Extra-long and -large sheets and sheets requiring stretching, both of the accepted and rejected, are transported to the stretching-shearing line for processing.

3.2.2 Coil shearing line

Line constitution is shown in **Fig. 5**; facility specifications are shown in **Table 3.** Specifications of main component units are shown in **Table 4.** Main features of this line are described below.

(1) Synchronization of Slitting Function
When there was a demand in the past for products whose sheet width was largely different from the raw material width, strip was slit at the slitting line before it was passed through the coil shearing line. In the new equipment, trimming allowance is greatly widened and the entry side is made capable of offset operation, so that strip for sheets after trimming will pass through the center of the line, thereby synchronizing the slitting operation. Residual strip forms a loop after trimming, and is led by turning toward the winding reel located on the ground. On the other hand, strip for sheets passes over the loop of the residual strip, reaches the leveller, where it is corrected, and is subjected to sheet cutting. Control is effected to ensure that the above operations and a series of operations of the residual strip from threading to winding-up operation can be accomplished smoothly.

(2) Realization of High Accuracy of Sheet Length
For the shear to cut sheets, rotary shears[4] are used. Cut length control is effected by the DDS (digital direct servo) control system. In the conventional DDS control rotary shear, the accuracy limit was considered to be ±0.5 mm at the time of constant speed operation within a speed ratio of 1 : 10, but at the present plant, a high accuracy of ±0.3 mm has been realized for both during acceleration and deceleration and during low-speed operation through the use of many new systems.

Table 3 Main specifications of coil shearing line

Item	Specification
Coil weight	17 000 kg max
Strip thickness	0.2-2.0 mm
Strip width	600-1 300 mm
Line speed	Cutting: 80 m/min max
	Piling: 120 m/min max
Sheet length	600-8 000 mm
Sheet width	600-1 300 mm
Residual coil width	300-500 mm
Residual coil weight	900 kg max

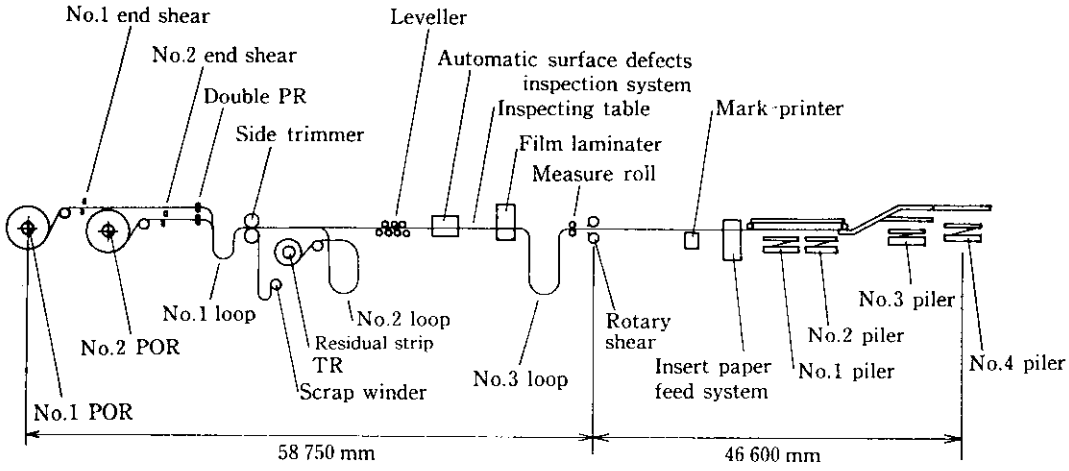

Fig. 5 Coil shearing line

Table 4 Main features of some facilities in coil shearing line

Item	Unit	Specification
Trimmer	1	Type: Pull-cut Diameter of arbor: 140 mm Diameter of cutter: 340 mm
Leveller	1	Type: 6 high roller leveller Roll size: Work roll; 50 mmϕ × 1 450 mm$L$ Middle roll; 45 mmϕ × 1 400 mm$L$ Back up roll; 100 mmϕ × 50 mm$L$ Levelling force: 49 000 kg
Shear	1	Type: Rotary shear Cutting cycle: 110 sheets/min at 728 mm length Blade shape: Double rake (Rake angle 40°) Control: Digital direct servo control
Piler	4	Type: Vacuum piler used rotary valves (Nos. 1 & 2), air float piler (Nos. 3 & 4) Piling sheet length: 600-8 000 mm Piling capacity: 3 000 kg/one piler
Film laminator	1	Film diameter: 600 mm max Film width: 600-1 300 mm Total back tension: 20 kg max

The new system employed includes a suppression of pulsation at the electric control system, measures for preventing a cutting impact drop, and prevention and correction of external disturbance to the mechnaical system.

(3) Practical Use of Vacuum Piler with Rotary Valves

The coil shearing line is provided with three prime pilers and one reject piler. For the two prime pilers (Nos. 1 and 2) out of the three, new system pilers, i.e., vacuum pilers with rotary valves have been used and put into practical services.

These new pilers have epoch-making functions, which were impossible to be accomplished by conventional pilers[5], such as permitting the individual use of No. 1 or No. 2 piler or simultaneous use of both pilers, and free selection of immediate piling or transit transportation of sheets, because instant changing-over of holding/releasing of a sheet has become possible.

Piling of each sheet is performed by determining the operation pattern and operation timing of many rotary valves according to given conditions such as thickness, length, and intervals of sheets, and by controlling these pattern and timing in combination with sheet tracking. For these control equipment, microcomputers, which perform computation by receiving from line computers information concerning sheet length and thickness, and hard logic controllers, which execute a high speed sequence control, are used.

(4) Synchronization of Film Laminator

In the past, vinyl film was laminated on sheets after sheet cutting at a separate line. In such a laminating line, vinyl film was cut according to a given sheet size by manual operation, resulting in poor efficiency. In the present line, however, a system has been used in which the vinyl film is laminated continuously on the strip, and later the strip is cut into sheets, thereby making marked improvement in efficiency.

In order not to disturb line efficiency by using this new system, it is necessary to splice the vinyl film without decelerating the line speed. **Figure 6** shows the laminator, which allows setting up of the vinyl film coil in use and the next coil to be used. When the residual amount of the coil in use reaches a preset quantity, the laminator goes into the state as shown in the figure. At a vinyl film coil splicing signal, the new coil is pulled out with the old film coil sheared off, thereby completing the splicing of old and new film coils.

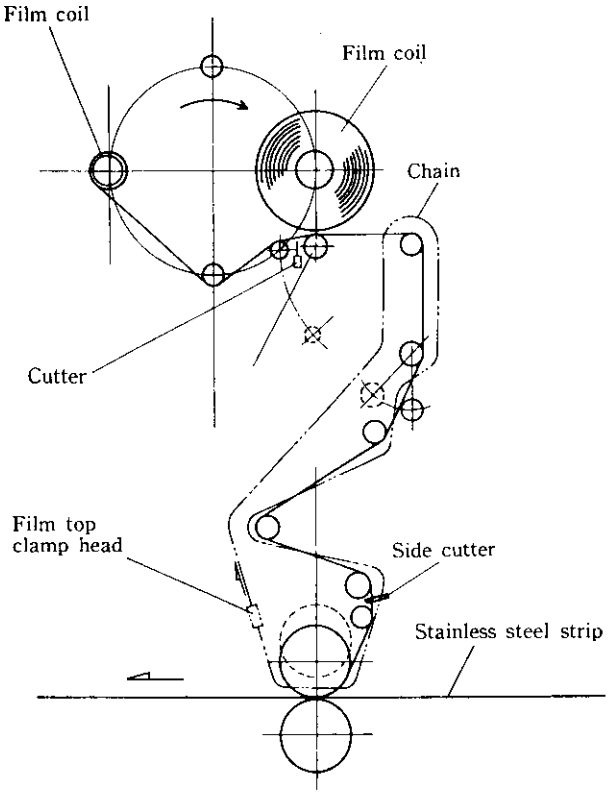

Fig. 6 Film laminator for stainless steel strip

(5) Automated Line Operation

This coil shearing line has been designed on the concept of "all that an operator has to do is just pressing the start switch." Threading of the residual width and splicing of the vinyl film at the laminator have already been explained. Beside the above, the following items have also been fully automated:

(a) Coil setting and widthwise quick position control
(b) Paying-off of coil top and end scraps and classifying coils according to types of steels.
(c) Threading operation from payoff reel to shearing line
(d) Width determination by side guide
(e) Random sampling of sheets for inspection purposes
(f) Polishing and cleaning of working roll of roller leveller
(g) Setting-up of the box, pallet board for packing, and pallet to the piler
(h) Marking
(i) Feeding of insert paper
(j) Weighing of piled sheets and residual strip after slitting
(k) Yield prediction of prime sheet products and automatic deceleration and stopping of line
(l) Inspection of scratch on sheets

3.2.3 Carriage conveyor

In some cases of the conventional finishing process, various examples of automation as shown above are performed on individual units within the sheet cutting line. But, post-piling operations such as sheet transportation, and selection, sorting-out and packing of reject sheets and goods-in-process were liable to become inefficient in using a crane and a large number of workers, because the dimensions and shapes of piling sheets to be handled were multifarious.

In the design of the new plant, the priority was given to the principle that instead of people moving about to handle things, things are automatically gathered and discharged to and from the work place. In order to achieve this, a line and its subsequent processes (such as reinspecting table, sheet packing zone, storage yard for rejects, and stretching-shearing line) are directly connected with conveyor lines to attain unattended transportation, and the receiving, storage and issuing of rejects and goods-in-process have also been automated by conveyor connecting to the automated warehouse.

In designing the carriage conveyor, the following constituted key problems to be solved:

(1) Meeting special requirements for handling multifarious dimensions (600 to 8 000 mm length, 500 to 1 250 mm width) and shapes (box, pallet board for sandwich package, and pallet).

Table 5 Main specifications of carriage conveyor

Item	Unit	Specification
Carrying out conveyor and conveyor for reinspecting table	7	Bushed rollor chain conveyor type Width: 835 mm No. of chain lines: 4 Chain pitch: 200 mm
Conveyor for packing zone	5	Slat chain conveyor type Width: 2 400 mm No. of chain lines: 4 Chain pitch: 150 mm
Sheet packing conveyor	4	Slat chain conveyor type Width: 1 150 mm No. of chain lines: 4 Chain pitch: 150 mm

(2) Sheets should be transported without binding, and yet no loosening of load will occur.[6]
(3) Estimation of appropriate value of the buffer amount which absorbs the imbalance in the capacities of two lines which are directly coupled.

To prevent the piled sheets from becoming loose, they are in principle transported by a chain conveyor, and the acceleration and deceleration speed is limited to 1.6 m/s^2 or below by using a cushion starter. The following types of chain conveyors are used: "S" roller-type conveyor chains are used for feeding sheets in the lengthwise direction, a slat chain conveyor is used for feeding them in the width direction, and a roller conveyor is used in combination at the transfer portion between the two conveyors where the use of the roller conveyor is necessary, but consideration is given to minimize deflection of rollers. The main specifications of carriage conveyors are shown in **Table 5**.

In estimating the buffer quantity, a storage quantity less than the level of one shift work was set up as allowance, after making simulations for all conceivable cases. Observation after operations of the conveyors indicated that there was still some allowance.

3.2.4 Automated warehouse

The automated warehouse means racks for goods-in-process which temporarily store sheet products not filling up the box, and also temporarily store reject sheets, until they fill up boxes which have been sorted out according to specifications and dimensions. Its specification is shown in **Table 6**.

Boxes are received or issued to and from the automated warehouse by using a stacker crane, which sends out fully-packed boxes of the accepted sheets and reject sheets to the packing line, and returns empty pallets for piling reject sheets to be reused in the coil shearing line.

Table 6 Main specifications of automated warehouse

Item	Specification
Capacity	238 pallets
Package length	100-3 190 mm
Package width	570-1 390 mm
Package heigth	400 mm max
Package weight	4 000 kg max
Stacker crane speed	100 & 5 m/min for travelling
	10 & 5 m/min for lifting

From simulations of the above-mentioned three functions of the automated warehouse and the reinspecting operation, the travelling speed of the stacker crane and the length of the buffer table in front of the reinspecting table have been determined.

3.2.5 Reinspecting table

To the reinspecting table, a pair of the unfilled-up box and the box of reject sheets both from the coil shearing line, and the box for selecting reject sheets from the automated warehouse as mentioned above are sent in proper timing. The arrangement for the respective boxes on the table has been so designed as to best facilitate inspecting and selecting by inspectors. At the reinspecting table, each and every reject sheet is inspected visually, and accepted sheets are thrown into the unfilled-up box, while the other sheets are put into the box for reject sheets. Information about the result of inspection is inputted by a voice input system, etc. When inspection is over, the boxes are automatically weighed and transported to the automated warehouse.

3.2.6 Stretching-shearing line

Constitution diagram of the line is shown in **Fig. 7**; its facility specifications are shown in **Table 7**. Specifications of its main components are shown in **Table 8**. The stretching-shearing line incorporates into a continuous line the sheet stretching function and the function of shearing the top, end, and sides of a sheet. The line also has functions of inspecting extra-long and -large sheets and laminating of vinyl film, and is connected to the coil shearing line with a carriage conveyor.

Next, the characteristics functions of this line are described.

(1) Depiler with Insert Paper Eliminator

Table 7 Main specifications of stretching-shearing line

Item	Specification
Sheet thickness	0.3-3.0 mm
Sheet width	600-1 300 mm
Sheet length	1 400-8 000 mm in stretching-shearing mode
	1 000-8 000 mm in vinyl laminating mode
	600-8 000 mm in inspecting mode
Line speed	40 m/min max

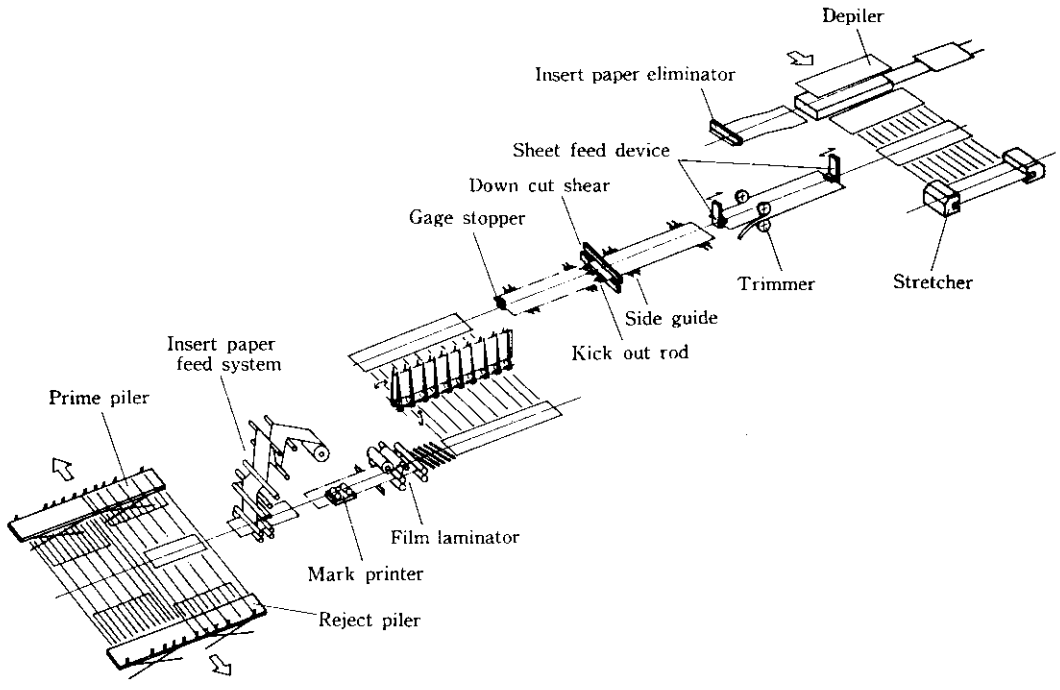

Fig. 7 Stretching-shearing line

Table 8 Main features of some facilities in stretching-shearing line

Item	Unit	Specification
Depiler	1	Type: Vacuum-cup type
Stretcher	1	Type: Oil hydraulic type Sheet width: 1 300 mm Sheet length: 8 000 mm Stretching strength: 300 t max
Trimmer	1	Type: Drive cut Diameter of arbor: 14 605 mm Diameter of cutter: 320 mm
Shear	1	Type: Down cutting by electric motor
Film laminator	1	Film diameter: 450 mm max Film width: 600-1 300 mm Total back tension: 20 kg max Automatic sheet feeding and film cutting
Piler	4	Type: Switch back method Piling sheet length: 600-8 000 mm Piling capacity: 3 000 kg/one piler

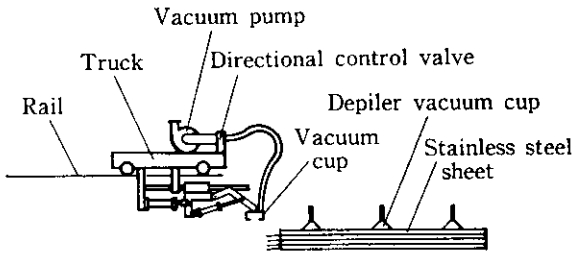

Fig. 8 Insert paper eliminator

The profile of the insert paper eliminator is shown in **Fig. 8**. In piling stainless steel sheets, it is a usual practice to insert paper between sheets to prevent the sheets from developing scratches. Consequently the insert paper must be removed when sheets are depiled by the depiler. This operation has been automated.

(2) Automation of Stretching Operation
Stretching operation which was carried out manually in the past is now automated. Namely, tension amount and return amount are preset according to a given material length, and the operator simply presses the start or stop button, with all other operations performed automatically.

(3) Side Shearing by Trimmer
Conventionally, side-shearing after stretching was performed by the gap shear. In the present line facilities, a system for performing side shearing by a trimmer during transportation has been employed, resulting in an efficient operation. Particularly for a material as long as 8 m, the effect of the above use is noticeable. It is important to maintain the linearity of the sheet during trimming, and for this purpose, a sheet carriage unit is provided.

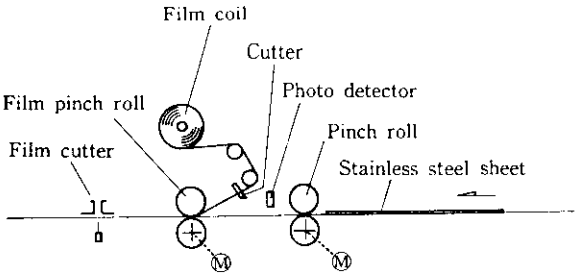

Fig. 9 Sheet film laminator

(4) Automatic Shearing of Top and Bottom Ends
The shears automatically cut the top and bottom ends of the sheet after its sides have been cut by the trimmer as explained above. To maintain right angles at the time of shearing, a positioning system has been developed which combines the side guide system and vertical roller system, and to improve length accuracy, a positioning and shearing system using a magnetic scale has been developed.

(5) Vinyl Film Lamination on Sheet
A series of operation has been automated in which a continuous vinyl strip is laminated on each stainless steel sheet transported by a conveyor, and the laminated vinyl film is sheared for each stainless steel sheet in the lengthwise and widthwise directions.

Constitution of the laminator is shown in **Fig. 9**. A slight gap is given between the leading and trailing stainless steel sheets, and after the vinyl film is laminated on the sheets, the cutter at the outlet side shears the vinyl film.

4 Computerized System and Automation

Since the new finishing plant handles multikind and small-quantity products, instruction information is complicated, and under such circumstances, it is necessary to carry out efficient operations for the respective lines and to track properly the flows of material and information between lines.

To cope with such situations, a hierarchically-constituted system—which has process computers at the center, a supervisory business computer at the higher order, and line control computers at the lower order and is provided with DDC computers and plant controllers below the line control computers—is used for operating and controlling the entire plant.

The entire system constitution is shown in **Fig. 10**;

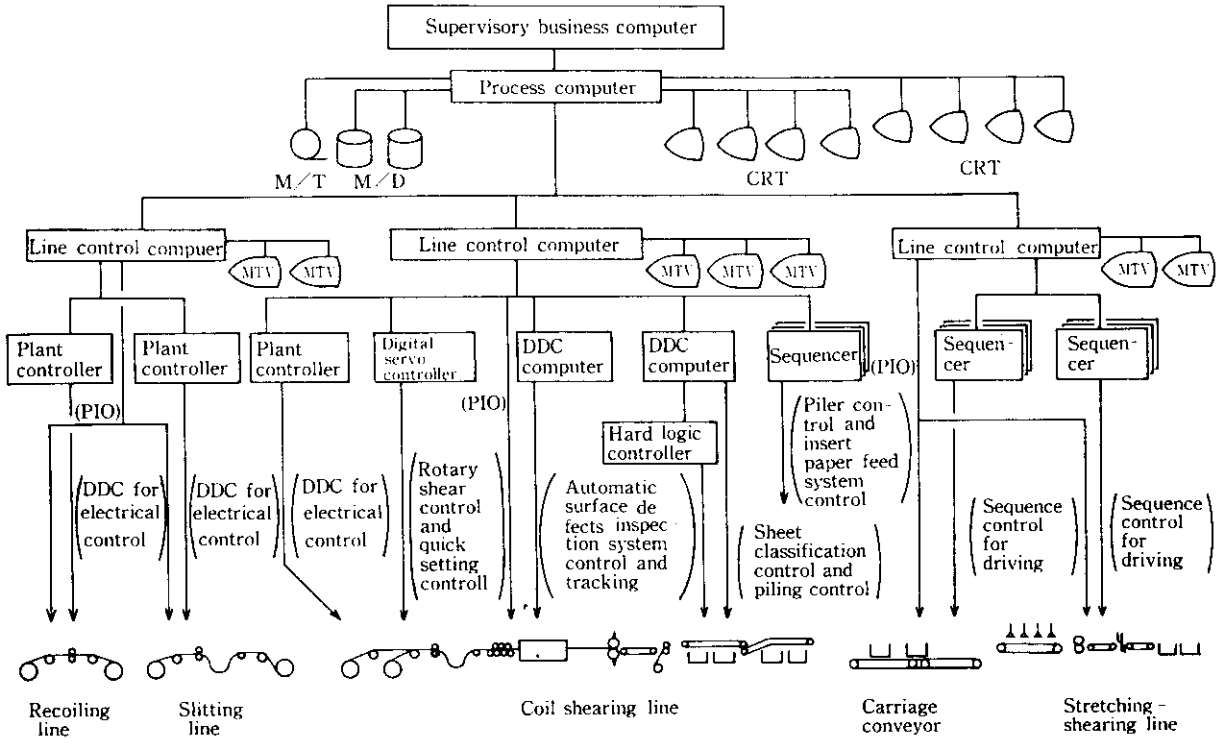

Fig. 10 Schematic representation of stainless steel finishing plant process computer and control system at Hanshin Works

specifications of computers and main controllers are shown in **Table 9**.

4.1 Computer System

The computer system has the following features:

(1) Hierarchical Constitution and Function Sharing
Process computers act as intermidiaries between the supervisory business computer and lower-order line control computers and plant controllers, and controls and monitors the entire finishing plant. Line control computers control operations of the respective lines, and perform line supervision and presetting data to electric control systems such as DDC computers, plant controllers, and sequences.

(2) Use of Microcomputers
Since the finishing plant consists of comparatively smaller lines for batch processing, moderate-cost control system constitution suitable for such a system is adopted. Namely, microcomputers are used to their full limits of functions, and also for dispersing the risks of troubles with operations.

(3) Operating Control by CRT
Operating efficiency of the batch processing line greatly depends on the stability of various machinery and equipment in the facilities, but is also greatly governed by the operation sequence and preparatory operation sequence on the part of the operator. Therefore, the combination of the process computers and line-control computers carries out operation guidance on CRT's and display the operation results per coil per instruction in graphs on CRT's and monitor televisions, thereby permitting instant operation analyses.

The functions of the computerized system are shown in **Table 10**.

4.2 Automation

Various lines in the new finishig plant handle multi-type and small-quantity products, and to achieve their efficient operation, wide-range automation has been practiced. An automatic controller to govern line operations mainly consist of the above-mentioned computer system and plant controllers which control the drive system and sequences, followed by sequencers, DDS controllers and hard logic controllers. These units are used for the control of the entire line, the entire section of the line, or in controlling single units such as the aforesaid paper inserting unit and shears.

Sensors are also used which are highly-developed units such as the surface scratch automatic inspection unit and automatic weigher, and many proximity sensors and optical sensors are also employed.

Drive systems consisting of direct current motors and eddy-current type variable speed motors are used at many locations in the coil shearing line to ensure stability and reliability of the line operation.

Table 9 Main specifications of computers and controllers

Item	Unit	Specification
Process computer	1	Model: PDP11-23 Memory capacity: 128 kw × 1 (IC and core) 10 Mw × 2 (disk) Memory cycle time: 0.5-1.075 μs CRT display: 6 set Hard copy equipment: 8 set Printer: 2 set I/O console CRT: 2 set Magnetic tape unit: 1 set Data communication: Modem and databus Interrupt level: 1-4
Line control computer (Recoiling line, slitting line, coil shearing line, carriage conveyor and stretching-shearing line)	3	Model: ROMCON 11-23 Memory capacity: 128 kw × 1 (IC and core) Memory cycle time: 0.5-1.075 μs Interrupt level: 1-4
DDC computer (Coil shearing line)	2	Model: ROMCON 11-2 Memory capacity: 28 kw (IC and core) Memory cycle time: 0.5-1.075 μs Interupt level: 1
Plant controller (Slitting line, coil shearing line)	2	Model: CP-320 Program capacity: 16 kw (IC) Mean cycle time: 3 ms/1 000 steps CRT display: 2 Number of process I/O: 8 000 max
Plant controller (Recoiling line)	1	Model: CP-315 Program capacity: 8 kw (IC) Mean cycle time: 1 ms/1 000 steps CRT Display: 1 set Number of processI/O: 1 152 max
Sequencer (Coil shearing line, carriage conveyor and stretching-shearing line	12	Model: UT 20 AP Program capacity: 2 048 steps max Cycle time: 20 ms Number of process I/O: 256

Table 10 Main functions of process computer system

Computer	Main function
Process computer	(1) Date communication with supervisory business computer and line control computers (2) Indication of operating condition and operating result on CRT (3) Decision of operating order (4) Data logging of dialy report and order report (5) Address control of coils in material coil yard and sheets in automatic warehouse (6) Data tracking from coil shearing line to sheet reinspection and packing line
Line control computer of coil shearing line	(1) Control of leftovers coil in the line and sheet amount (2) Setting line condition (sheet length, sheet width, line speed, etc.) (3) Control of piling condition (4) Data tracking of sheets from inspecting zone to piler (5) Indication of piling sheet numbers
Line control computers of slitting line and recoiling line	(1) Control of coil length (2) Setting line condition (3) Indication of coil length and weight

5 Conclusions

A stainless steel finishing plant was constructed which included facilities ranging from the storage yard of material coils for the finishing process to the product storage yard. New attempts have been made particularly at processes where sheet products are handled, with successful results confirmed. This plant is epoch-making facilities in that coils supplied to the coil shearing line come out as sheets flowing into the product storage yard with no use of a crane. As a result, the labor productivity at the new finishing plant has been improved to twice as much as that of the conventional facilities of the same production scale.

The following techniques of the company's own development employed in the new finishing plant can also be utilized in other fields as new techniques:

(1) On-line inspection, box-packing, and reinspecting system

(2) Synchronization of slitting function by unique winding method of residual strip
(3) Vacuum piler using rotary valves
(4) Continuation and automation of stretching and shearing operations
(5) Automation of vinyl film laminating on sheets

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